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DEPARTMENT OF REGISTRATION AND EDUCATION

SALEM LIMESTONE OIL AND GAS PRODUCTION IN THE KEENVILLE FIELD, WAYNE COUNTY, ILLINOIS

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Errata

Some locations listed above well logs in figures 3 and 4 are incorrect. Refer to Appendix B for correct locations.

The index maps for figures 3 and 4 are incorrect. The correct index maps are shown below.

Figure 3

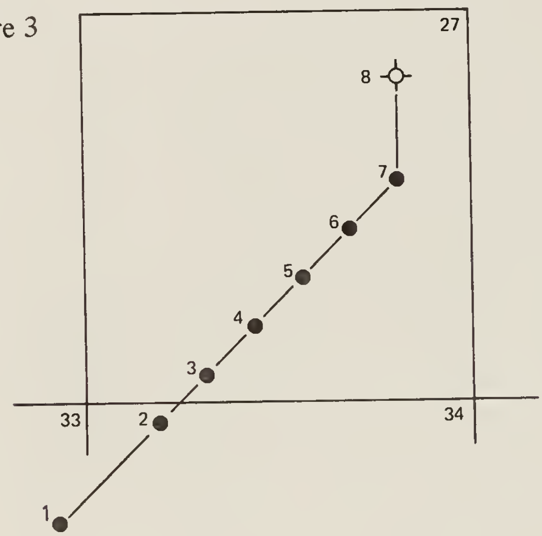
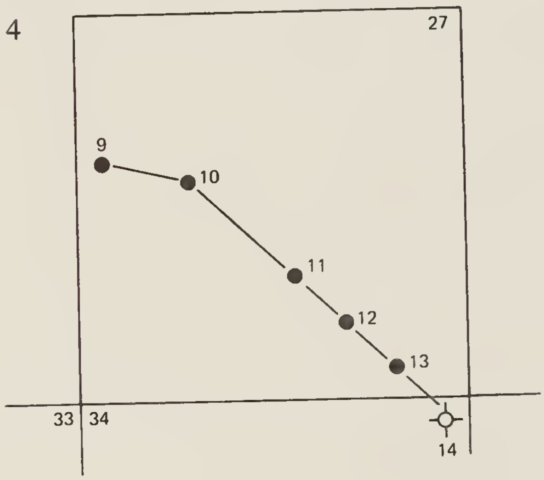


Figure 4



SALEM LIMESTONE OIL AND GAS PRODUCTION IN THE KEENVILLE FIELD, WAYNE COUNTY, ILLINOIS

D.L. Stevenson

ABSTRACT

Oil has been produced from the Salem Limestone of Valmeyeran (middle Mississippian) age in Illinois since 1939. In 1972 the discovery of Salem oil at Zenith North field in Wayne County, Illinois, stimulated a resurgence of Salem exploration in the Illinois Basin. By the end of 1977, activity had resulted in 3 new field discoveries and 24 new pool discoveries in the Salem of Illinois.

One of the most promising of these discoveries was in the Keenville field, in T. 1 S., R. 5 E., Wayne County, Illinois. The discovery well was completed early in January 1977, and by the end of the year 40 wells had produced approximately 760,000 barrels of Salem oil.

The oil is produced from a biocalcarenite (predominantly sand-sized fossils and fossil fragments), with highly variable porosity and permeability, which lies about midway between the top and bottom of the formation. No structural closure is evident on key marker beds above the Salem, but some closure is created by the tendency of the producing zone to occur increasingly lower in the section in an up-dip direction.

Water-free oil production was obtained in many wells by setting pipe through the reservoir and perforating above the oil-water contact, as determined by examination of drill cuttings.

The oil produced is accompanied by gas with a heating value of about 1500 BTU/ft^3.

To date, most of the oil accumulations in the Salem have been found by drilling below shallower, producing zones on prominent structures. The presence of reservoirs within the Salem, such as the one at Keenville, has been difficult to predict prior to drilling. The recent increase in the number of holes drilled to or through the Salem should add to our knowledge of its depositional and diagenetic history and help in further oil exploration.

INTRODUCTION

The Salem Limestone of Valmeyeran (middle Mississippian) age has produced oil in Illinois since 1939. The first Salem discoveries were in Barnhill field in Wayne County and Salem field in Marion and Jefferson Counties. Since then, oil accumulations have been encountered in the Salem over a wide area in Illinois (Howard, 1967).

Since the early 1970s, renewed interest in exploring for oil in the Salem has been shown by Illinois Basin operators. This interest was stimulated to a great extent by the discovery of Salem oil at Zenith North field in Wayne County. In February 1972, the Charles Booth #1-A L. P. Cook (Sec. 21, T. 2 N., R. 6 E.) was completed in Zenith North. The reported initial production rate was 160 barrels of oil and 200 barrels of water per day. From 1972 through 1977, the number of Salem discoveries classified as either new field or new pay zone discoveries increased each year. Table 1 shows the fields in which these discoveries have occurred according to year of Salem discovery.

The twenty-seven Salem oil discoveries during this six-year period involved eleven counties. Much of the Salem exploration activity in this period occurred in Wayne County, and more of the new Salem production was found in that county than in any other. Figure 1 is an index map of Illinois showing general thickness of the Salem Limestone and the eleven counties mentioned above. In all, nine new pay zones were found in the Salem of Wayne County. The amount of oil produced from these new Salem pools was large enough to make a significant contribution toward the reversal in the decline curve showing total oil production in Illinois. This curve had a slope reflecting a 10 to 12 percent per year decline for several years prior to 1975. In 1976 the total oil production in Illinois showed an increase of 0.8 percent over 1975. This increase was due largely to oil produced from the Salem (Statler et al., 1977).

One of the most noteworthy new pay zones in the Salem was found at Keenville field. It is economically significant because of the relatively high production rates: a high percentage of the wells flowed at initial rates of 100 to 300 barrels a day. The Salem pays at Keenville are also geologically significant inasmuch as they occur on a southeastwardly plunging structural nose with no apparent closure. Though the Keenville field may not represent a typical Salem oil accumulation, it has characteristics that are more or less common to many Salem pools.

HISTORY OF KEENVILLE FIELD

Keenville field (T. 1 S., R. 5 E., Wayne County, Illinois) was discovered with the drilling of the Gulf # 1 Anderson (Sec. 26, T. 1 S., R. 5 E.) in February 1945. Initial production of 11 barrels of oil and 240 barrels of water per day was reported from the Aux Vases Sandstone. Ohara, Spar Mountain, and McClosky pays were added by drilling during 1946. During the next 30 years, over 95,000 barrels of oil were produced from these four pays, and 1976 production totalled about 1500 barrels of oil.

In December 1976, the Farrar # 1 Roy Reed was spudded in Sec. 27. T. 1 S., R. 5 E. In January 1977, this well was reported as completed; the initial rate was 335 barrels of oil flowing per day with no stimulation. During 1977 the number of wells producing from the Salem grew to 40. Many of these were completed as flowing wells and several still flowed in 1978. The number of producing wells is approaching 50, but since several were not yet reported as completed at the time of this writing, not all are shown on the maps included in this report.

TABLE 1. New field and new pool discoveries in the Salem Limestone of Illinois from January 1, 1972 to December 31, 1977

Year	Field	County	New Field	New Pool
1972	Zenith N.	Wayne		X
1973	Keensburg S.	Wabash		X
	Maunie S. C.	White		X
1974	Louisville	Clay	X	
	Lillyville N.	Cumberland	X	
	Bone Gap E.	Edwards		X
	Brubaker	Marion		X
1975	Evers	Effingham		X
	Exchange	Marion		X
	Berryville C.	Wabash		X
	Johnsonville S.	Wayne		X
	Goldengate C.	Wayne		X
1976	Kell N.	Marion	X	
	Samsville W.	Edwards		X
	Rural Hill N.	Hamilton		X
	Browns E.	Wabash		X
	Rinard N.	Wayne		X
	Herald C.	White		X
1977	Keenville	Wayne		X
	Keenville E.	Wayne		X
	Coil	Wayne		X
	Mattoon	Coles		X
	Halfmoon	Wayne		X
	Mayberry	Wayne		X
	Springerton S.	White		X
	Whittington	Franklin		X
	Rochester	Wabash		X

GEOLOGY

Stratigraphy

In a regional study of the Salem Limestone, Lineback (1972) discussed the facies of the Salem and the nature of the contacts with the overlying St. Louis and underlying Ullin Limestones. Lineback's work provides those interested in exploring for oil in the Salem with an interpretation of the depositional history of these units based on the various facies found in the Salem and adjacent formations. The reader is referred to Lineback's (1972) list of references as a source of additional information on the Salem Limestone in the Illinois Basin.

Figure 2 is a copy of an electric log through the lower Chesterian formations and into the Ullin Limestone. This log, selected from one of the Keenville test holes, shows a typical set of resistivity and spontaneous potential curves for logs run in that field as well as the position of the Salem pay zone at Keenville.

Figures 3 and 4 are cross sections drawn through the Keenville field to illustrate the stratigraphic position of the pay zone with respect to the top of the Salem Limestone. These cross sections are based on holes drilled along essentially straight lines at right angles to each other. Figure 3 represents holes drilled along a northeast-south-

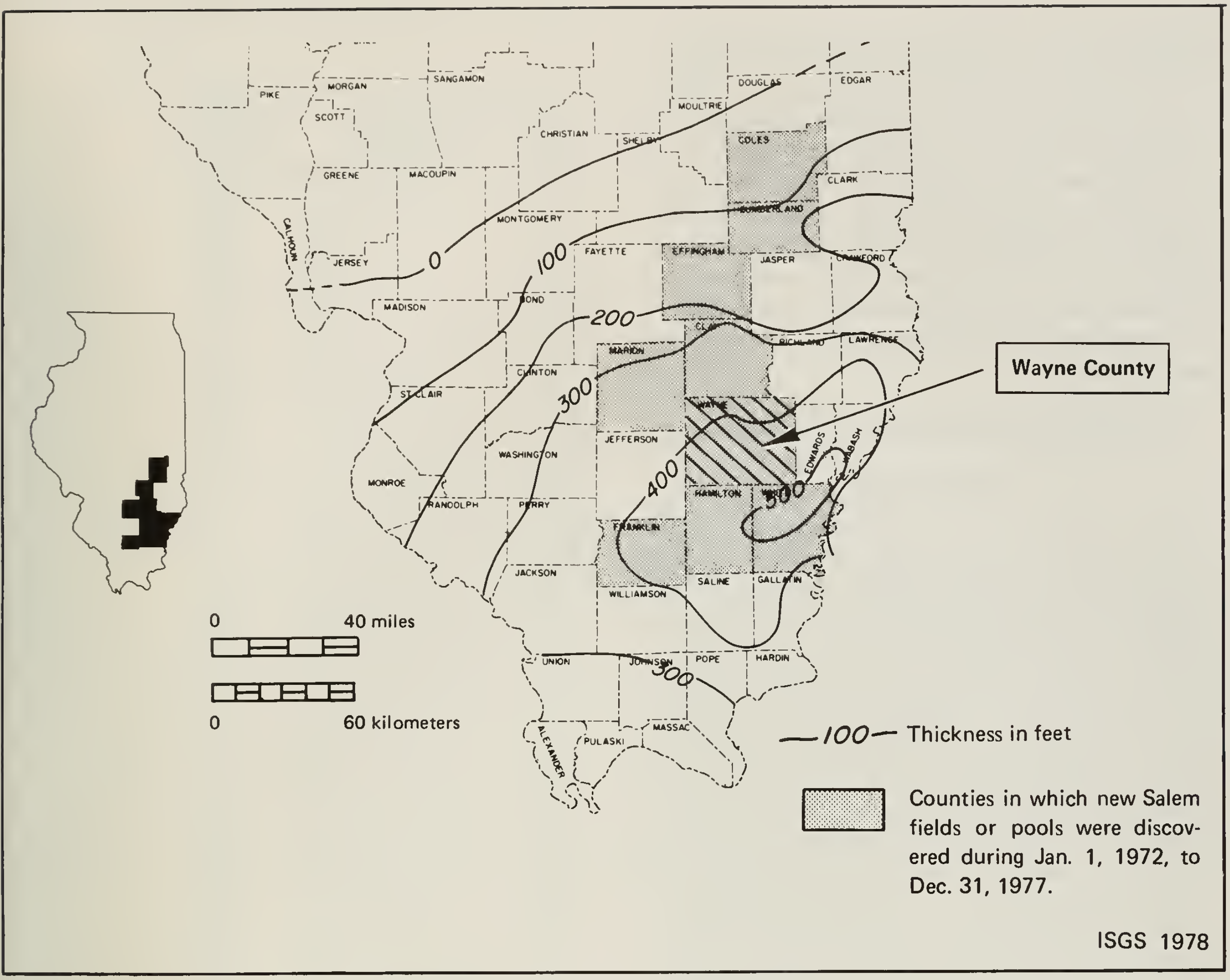


Figure 1. Index map of Illinois showing general thickness of the Salem Limestone.

west line, and figure 4 shows those in a northwest-southeast line.

In figure 3, the top of the pay zone is roughly parallel to the top of the Salem Limestone. In figure 4, the top of the Salem pay zone and the formation top are more or less parallel in the right half of the cross section, but on the left half—toward the northwest—these lines diverge as the pay zone migrates "down section." This divergence reverses the "dip" of the pay zone at the northwest end of the field. Figure 5, a map of the top of the main Salem pay zone, illustrates the closure created by this variation in stratigraphic position of the pay zone with respect to the top of the formation. The highest well with respect to the top of the pay zone is the Farrar # 1 Johnson-Keen unit (SW NW SE Section 27). This well was completed by perforating a 40-foot section of oil saturation. This is the thickest, continuous oil-saturated section in the Salem pay in Keenville.

Structure

The structure associated with the oil accumulations at Keenville can be described as a southeastward plunging nose. Figure 6 is a map of Wayne County showing the structure contoured on the top of the Karnak Limestone Member (Ste. Genevieve). Of the areas of Salem oil production shown, many, including Keenville, display little or no closure. Also, in most cases, the oil accumulation is offset toward one of the flanks rather than centered on top of the structures. The lack of closure on the Karnak is shown in larger scale in figure 7. The lack of reversal in the northwest or up-regional dip-direction suggests that folding was not wholly responsible for trapping the oil at Keenville. Instead, lateral facies variations in the reservoir may have produced the permeability barriers preventing the oil from escaping. These permeability variations would also help to explain why the oil accumulations are not located on the top of the structures. This would lead one to classify most Salem oil pools as stratigraphic accumulations, even though many display structural influence.

CHARACTERISTICS OF RESERVOIR

General lithology

The entire Salem Limestone in the area of Keenville field consists predominantly of sand-sized fossils and fossil fragments. This lithology is referred to as biocalcarenite, and it typifies the thickest part of the Salem in the Illinois Basin (Lineback, 1972). The reservoir properties (porosity and permeability) of this biocalcarenite vary considerably depending upon the type and amount of interstitial cementing material. These variations are sufficiently extreme to produce a good reservoir in one place and an effective barrier to fluid migration in another. The fact that oil accumulations have been found in several zones in the Salem, from the top to the bottom, demonstrates the existence of reservoir beds alternating with relatively impermeable "sealing" beds composed of similar lithologies.

Porosity and permeability

The Salem reservoir at Keenville is developed slightly below midpoint of the formation (fig. 2). The typical or average reservoir properties cannot be described because core analyses are available on only one of the producing wells. Examples of porosity and permeability measured throughout a 53-foot section are available in a core analysis report on the Farrar # 4 Roy Reed in Sec. 27, T. 1 S., R. 5 E., Wayne County. These data are listed in table 2. The average values for all samples are shown in table 3. The Farrar # 4 Roy Reed was completed as a producing oil well. The initial production reported was 100 barrels of oil and 125 barrels of water, pumping, per day. The casing was perforated opposite two intervals, 3587 to

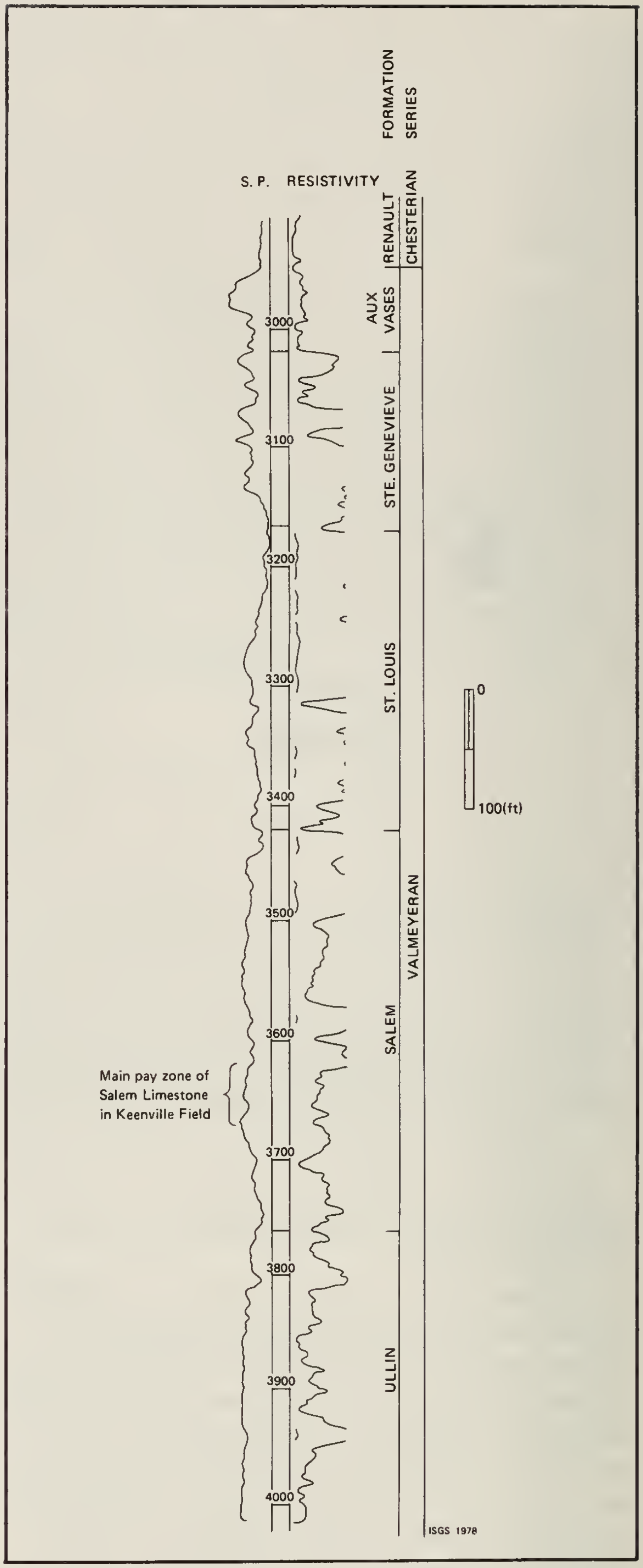


Figure 2. Portion of a typical electric log in Keenville showing key formation tops and position of main Salem pay zone.

TABLE 2. Selected results of core analysis from a well in Keenville field

Depth of core (ft)	Vertical permeability (MD)[a]	Horizontal permeability (Average MD)	Porosity (%)
3592.6-93.6	3.7	2.2	7.7
3594.0-94.6	1.0	0	1.5
3595.3-96.0	.8	0	2.3
3596.0-96.4	.6	.2	1.4
3596.4-97.0	.9	0	2.1
3597.0-98.0	1.2	.3	2.7
3593.9-98.7	1.0	0	5.9
3598.7-99.2	.7	0	2.5
3599.4 -.1	1.1	31.6	8.4
3600.3- 1.1	1.1	27.2	9.6
3601.4- 2.3	1.5	.6	5.3
3602.9- 4.0	1.4	.8	2.2
3604.2- 5.1	1.6	1.3	6.3
3605.4- 5.9	.8	4.9	9.0
3606.1- 7.0	10.0	27.9	12.1
3607.2- 8.0	17.1	329	12.2
3608.2- 8.9	10.1	23.0	10.4
3609.0- 9.5	2.6	5.5	11.5
3609.8-10.0	2.0	.9	6.2
3610.3-11.3	.8	3.0	6.6
3611.5-12.0	1.2	.9	6.2
3612.2-13.0	2.3	42.6	7.5
3613.3-14.1	1.0	105	5.7
3614.3-15.1	1.4	.5	5.3
3615.3-16.2	3.5	12.8	9.0
3616.2-16.6	6.9	35.5	10.5
3617.3-18.0	1.2	5.7	7.8
3618.0-18.0	2.0	145	5.4
3619.2-20.0	4.9	35.1	11.5
3620.2-21.1	14.3	33.8	11.5
3621.2-21.7	7.3	42.1	12.3
3622.1-23.3	1.1	2.6	7.1
3623.5-24.4	.8	0	1.7
3624.5-25.4	1.1	9.2	7.8
3625.5-26.0	7.4	18.5	10.0
3626.2-26.7	4.6	19.6	8.6
3627.0-27.7	.8	12.9	8.5
3627.9-29.0	1.5	2.7	7.4
3629.1-29.9	1.0	2.7	3.1
3630.0-30.6	1.5	90.8	7.2
3630.7-31.2	6.7	59.9	10.4
3631.5-32.0	1.8	21.0	11.8
3632.2-33.0	8.0	1029	14.1
3633.2-34.0	2.4	32.7	15.6
3634.2-35.1	4.4	83.2	14.3
3635.1-35.9	17.7	95.5	14.9
3636.1-37.1	4.1	31.5	15.3
3637.1-37.1	5.8	42.0	15.1
3638.5-39.2	7.0	46.4	15.6
3640.0-41.0	12.1	68.2	14.1
3641.3-42.0	15.6	179	15.5
3642.3-43.0	1.3	45.1	11.7
3643.2-44.0	3.9	3.9	7.7

[a] MD = millidarcy

3590 and 3601 to 3611. This is neither the best nor the worst initial production of the producing wells in the pool, so one might assume that the reservoir characteristics represent something between the best and worst of those encountered in the pool. Based on these limited core analysis data, one can conclude only that the porosity and permeability vary considerably within the zone that provides the oil reservoir at Keenville.

One piece of the analyzed core was selected for closer examination. The selected piece was a sample representing the interval from 3607.2 to 3608 feet (table 2). Figure 8 is a greatly enlarged photograph of a small portion of an acetate peel taken from the core. The peel was produced by polishing a flat surface of the rock, lightly etching the surface with dilute (5%) HC1, and thoroughly drying the sample. When the polished face was dry, it was wetted with acetone, and a sheet of acetate was laid on the wet face. After the acetate dried, it was peeled off, and a very thin film of rock adhered to it. This peel was placed in a photo enlarger to expose a negative, which in turn was used to produce the print shown in figure 8. The characteristic fossils and fossil fragments can be seen. The pore spaces appear as clear areas. Areas that are nearly clear represent interstitial sparry calcite. Nonreservoir portions of the Salem differ from this specimen in that they contain more interstitial calcite and therefore possess lower permeability and porosity. Any part of the Salem that consists of this typical biocalcarenite would probably serve as a reservoir if the conditions preventing the complete or nearly complete filling of these interstices prevailed during and following deposition.

TABLE 3. Average results of core analyses shown in table 2

Horizontal permeability range	Number of samples	Vertical permeability (Average MD)	Horizontal permeability (Average MD)	Porosity (%)
> 1000 MD	1	8.0	1029.1	14.1
100 - 1000 MD	4	8.9	190.0	9.7
10 - 100 MD	24	5.7	40.7	11.4
1 - 10 MD	11	1.7	3.9	7.4
0.1 - 1 MD	7	1.3	.6	4.1
< 0.1 MD	6	.8	.0	2.6
Average of all samples	53	4.0	53.1	8.6

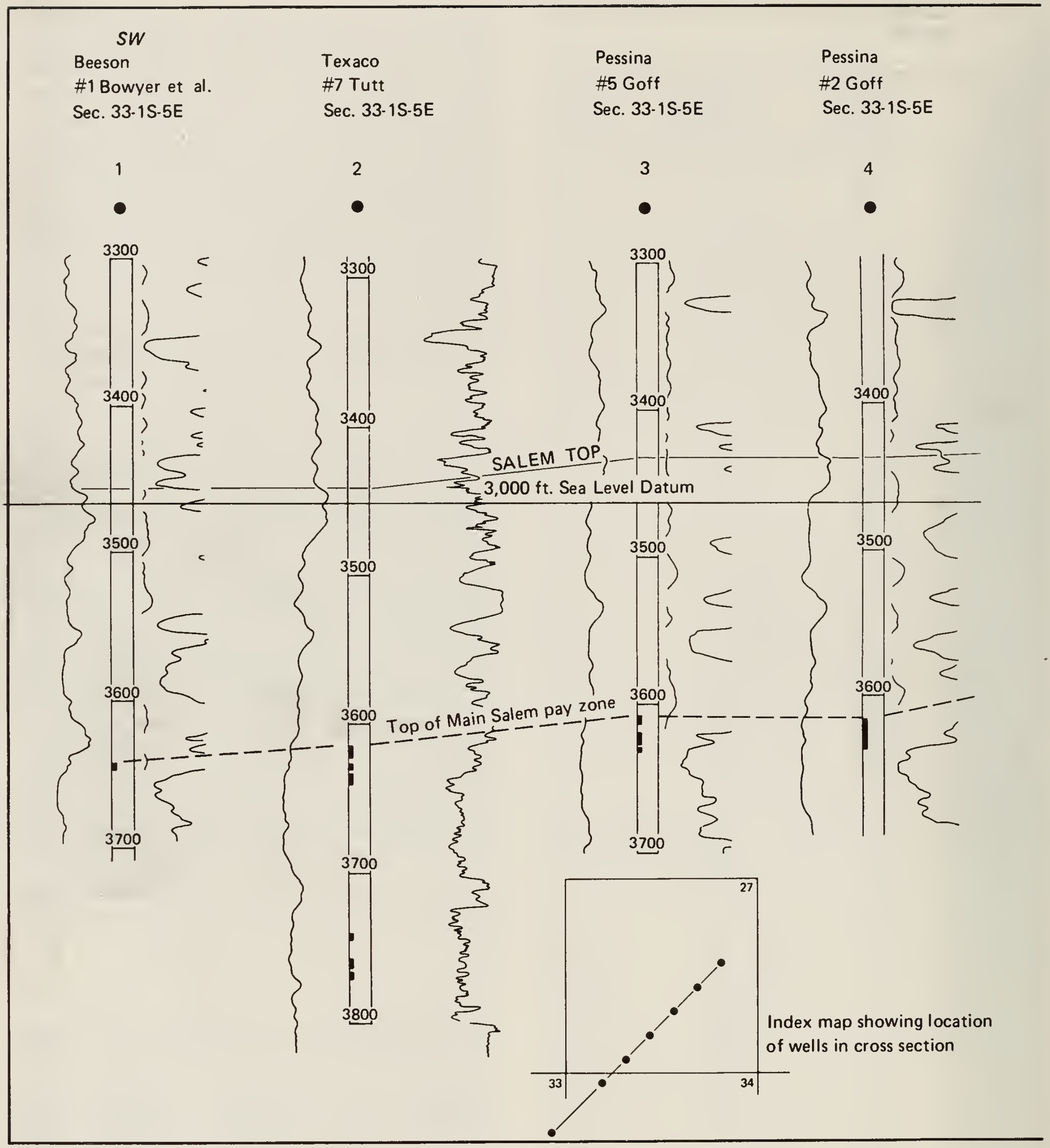
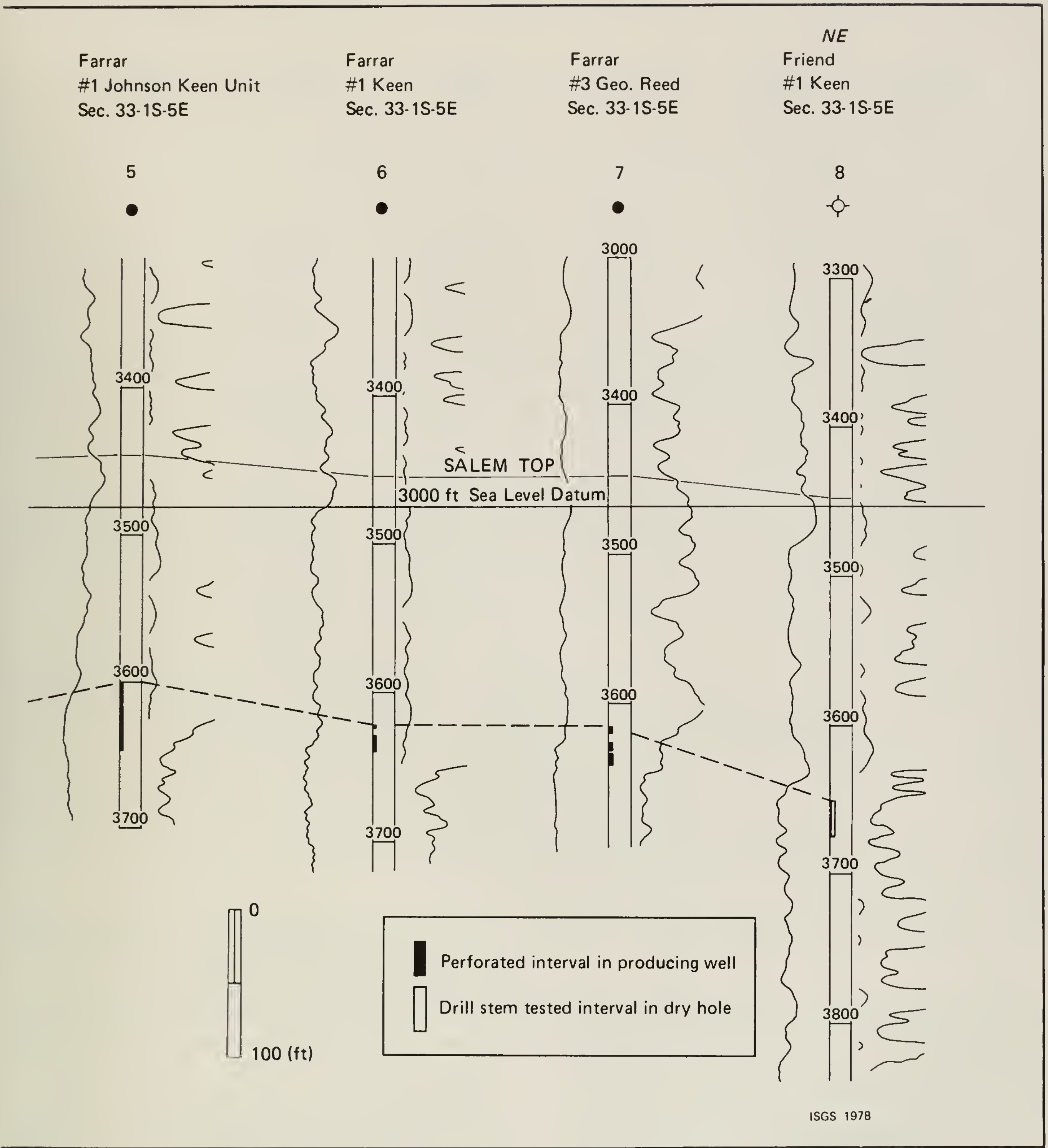


Figure 3. NE-SW Cross section across Keenville field.


NE
Farrar
#1 Johnson Keen Unit
Sec. 33-1S-5E
Farrar
#1 Keen
Sec. 33-1S-5E
Farrar
#3 Geo. Reed
Sec. 33-1S-5E
Friend
#1 Keen
Sec. 33-1S-5E
5
6
7
8
3000
3300
3400
3500
3600
3700
3800
SALEM TOP
3000 ft Sea Level Datum
0
100 (ft)
Perforated interval in producing well
Drill stem tested interval in dry hole
ISGS 1978

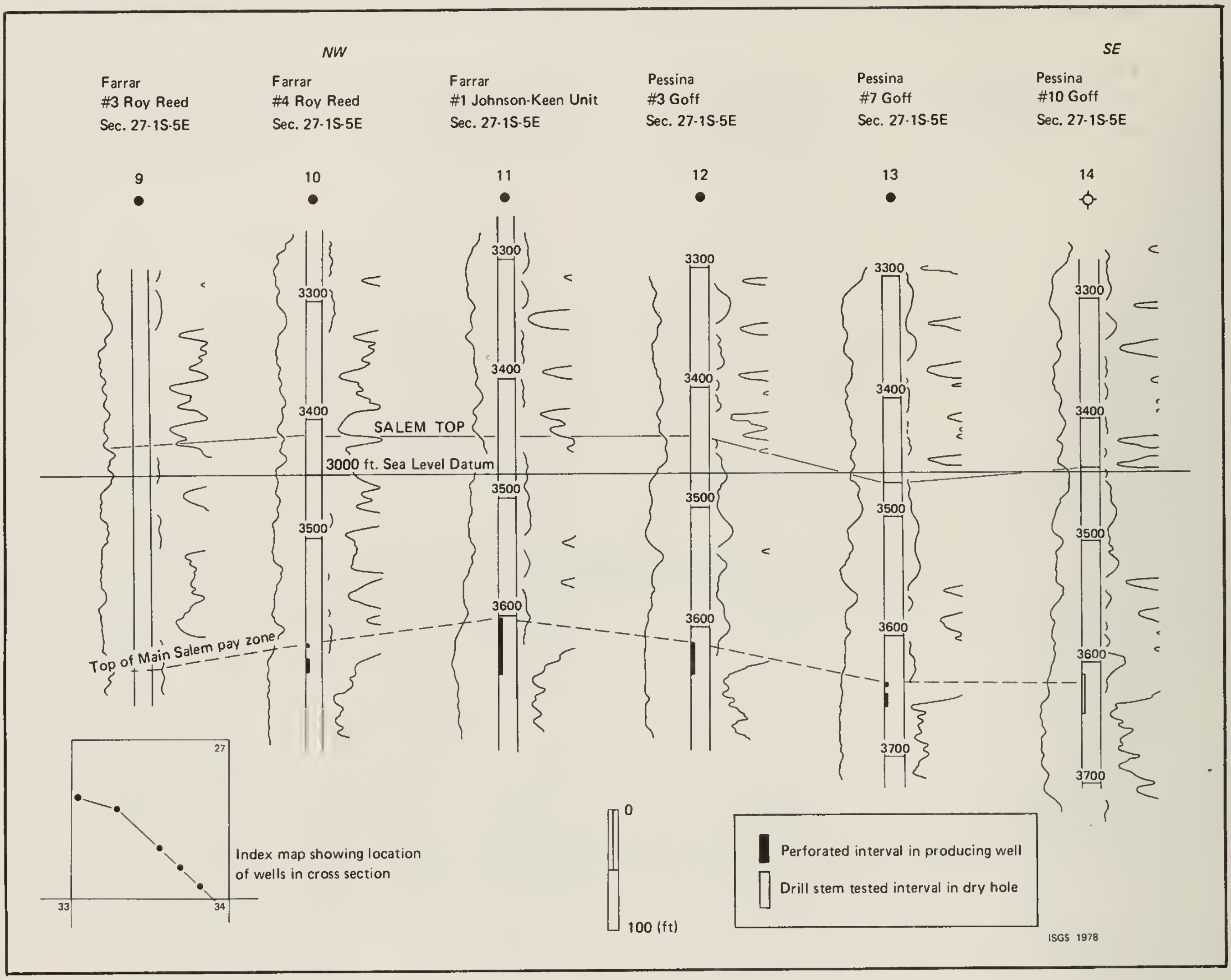


Figure 4. NW-SE Cross section across Keenville field.

PRACTICES FOR COMPLETION[1]

The normal completion procedure for Salem producers in Keenville is to set casing through the zone considered to be productive. The casing is then perforated opposite the portion of the reservoir thought to be oil-saturated. The top of this zone coincides with the top of the porosity as determined from geophysical log interpretation. The bottom of the perforated interval is determined by the depth of the oil-water contact.

According to one geologist who watched several Keenville wells during drilling and completion, the oil-water contact in the Salem is quite distinct and is recognizable by close examination of drill cuttings (Marshall Daniel, personal communication, 1977). The oil-saturated section yields cuttings that are relatively clean, while the water-wet zone produces cuttings that are coated with very fine white powder. Wetting the latter cutting produces a milky fluid that can be removed only by several rinsings in water. When Daniel analyzed the fine powder from these coated cuttings by X-ray diffraction, the powder was determined to be calcite.

Following perforation of the casing, some wells were treated with acid and some were completed naturally, that is, with no stimulation of any kind. Flowing wells yielding no water were typical of those completed in the Salem in the central portion of Keenville. The cost per well following this procedure was estimated at around $110,000.

[1]The following discussion is based largely on the data obtained from scout reports (Petroleum Information Corp. and Scout Check Inc.) and conversation with Fletcher Farrar, one of the major operators in the pool.

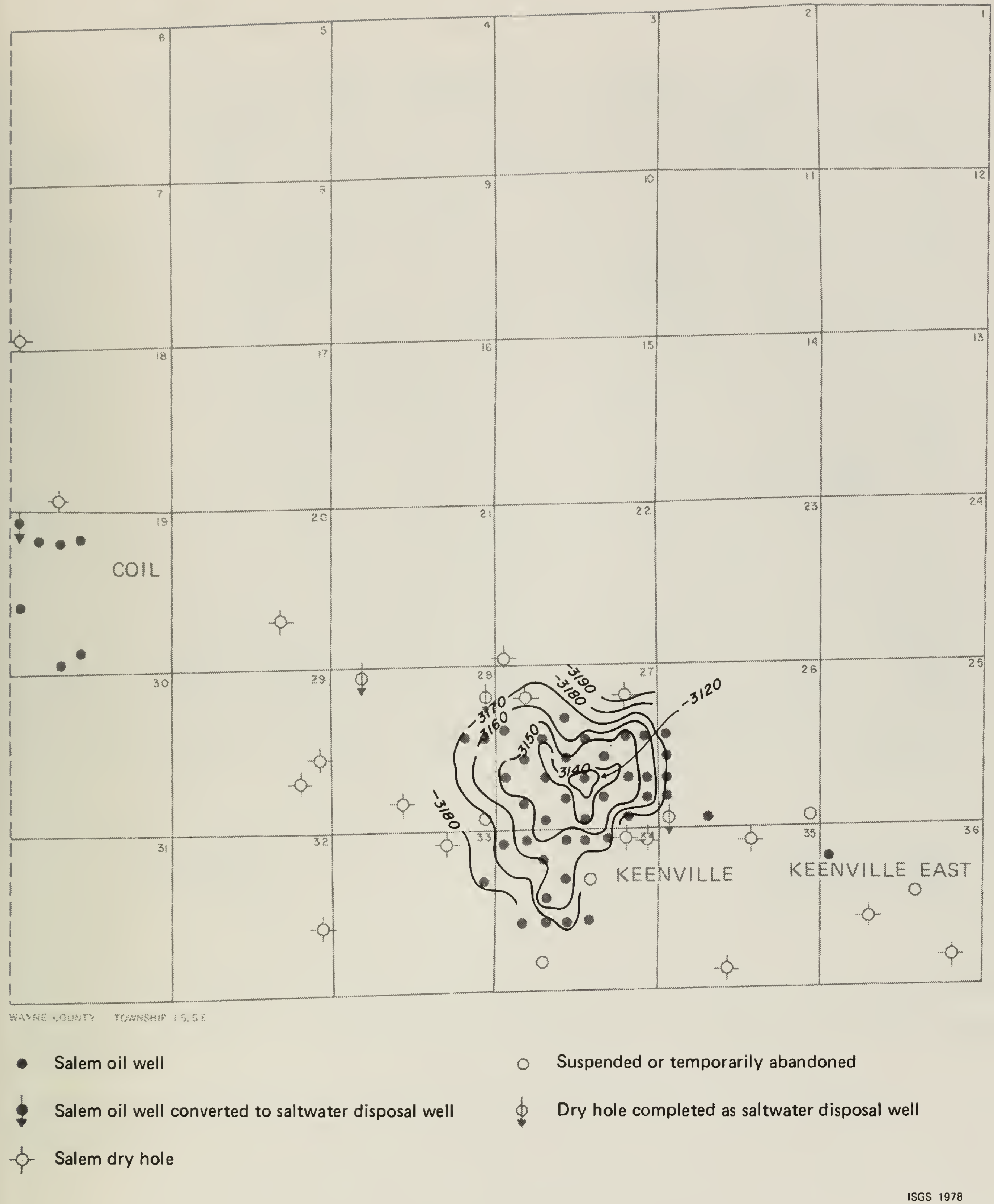


Figure 5. Structure map of top of main Salem pay zone in Keenville field.

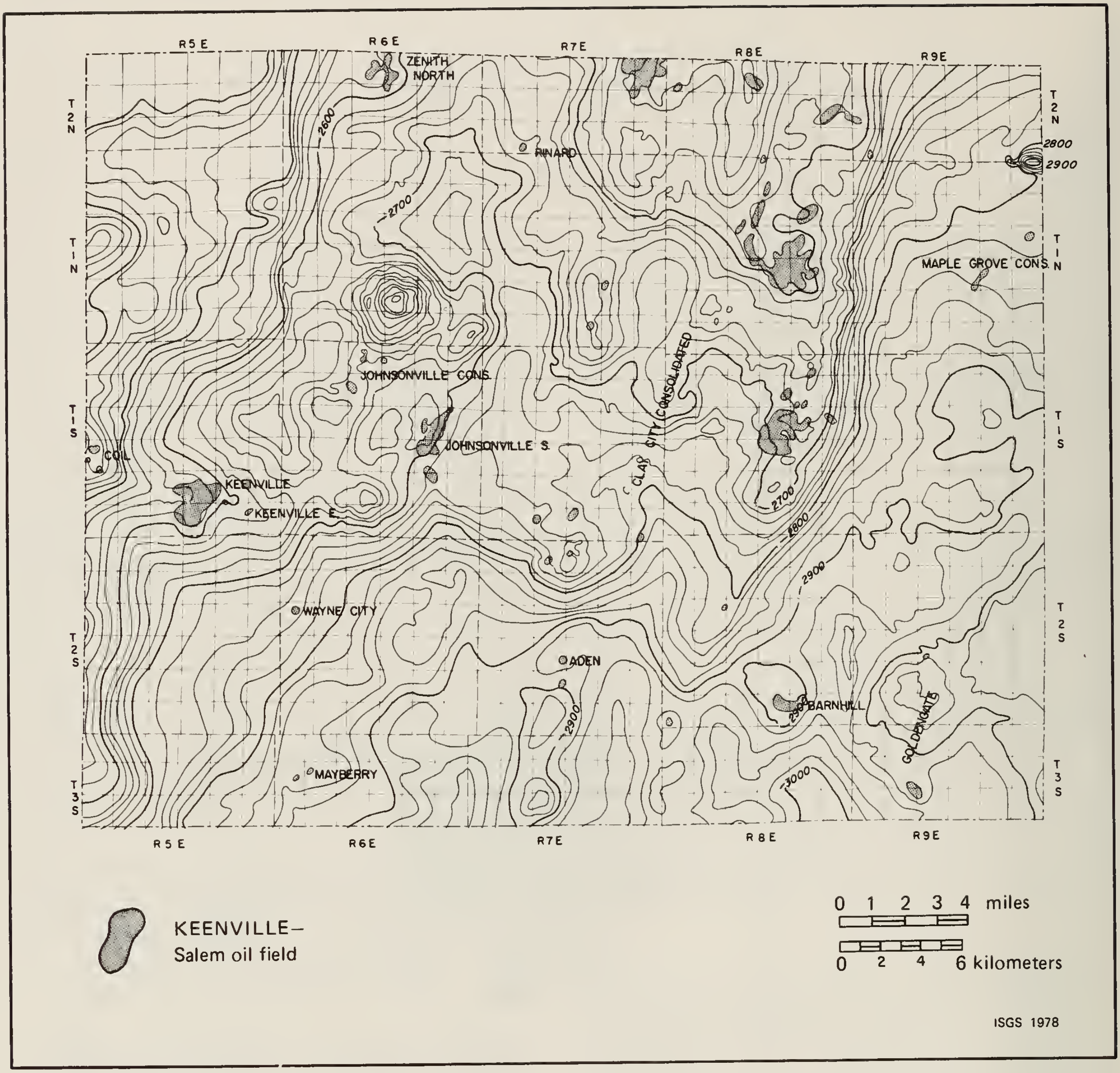
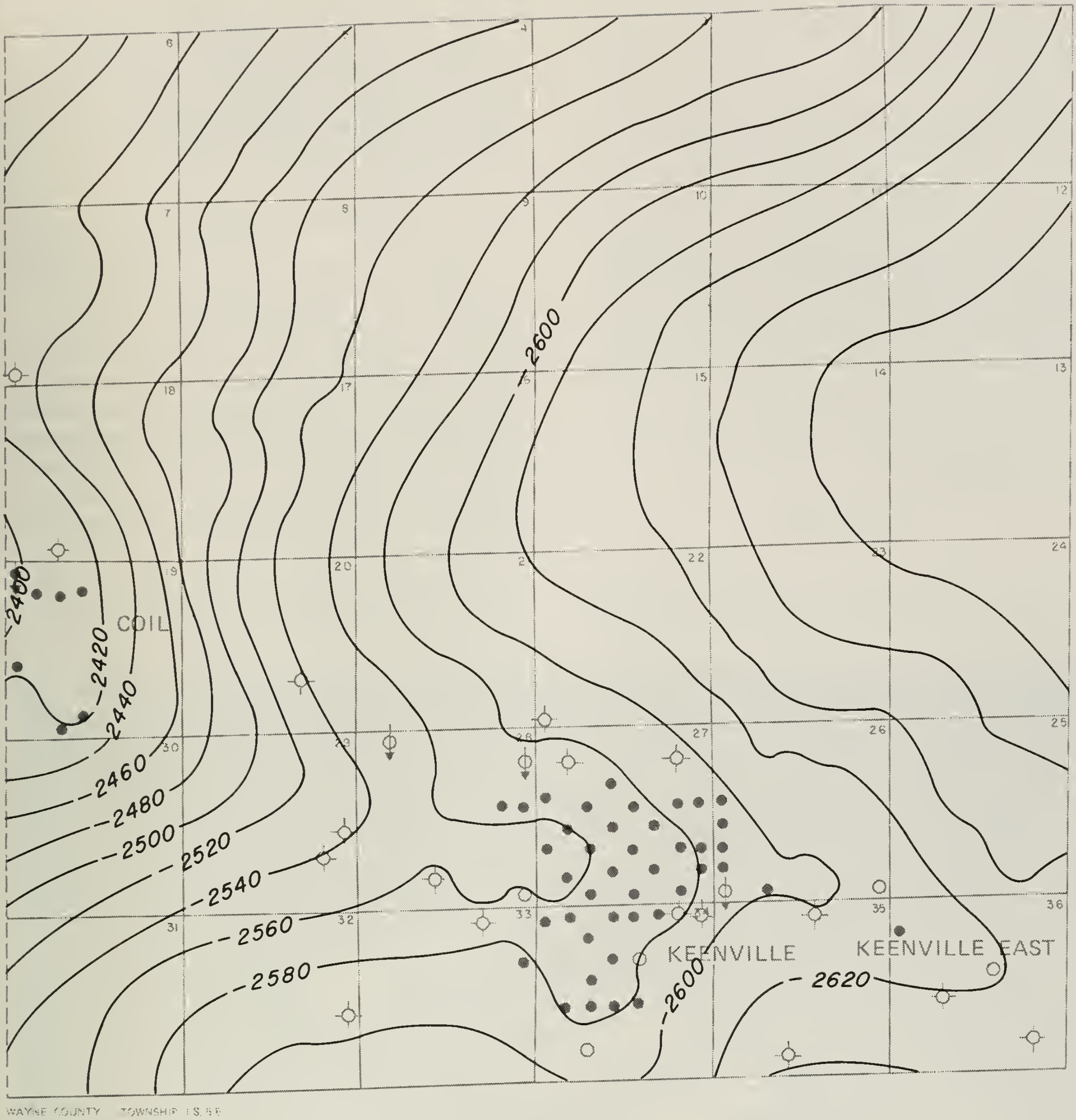


Figure 6. Structure of top of Karnak Limestone Member (Ste. Genevieve) showing location of Salem pools, Wayne County.



- Salem oil well
- Salem oil well converted to saltwater disposal well
- Salem dry hole
- Suspended or temporarily abandoned
- Dry hole completed as saltwater disposal well

ISGS 1978

Figure 7. Structure of top of Karnak Limestone Member (Ste. Genevieve), Keenville area.

This cost was divided more or less equally between drilling and completing.

HISTORY OF PRODUCTION

Oil Production

The monthly oil production from the Salem Limestone in Keenville is shown in figure 9. The peak production was reached in May 1977, when over 84,000 barrels were produced. By December 1977 the production had declined to a little over 64,000 barrels during that month. By the end of 1977 the total Salem oil production reached about 760,000 barrels, as shown by the cumulative production curve on figure 10.

Gas Production

The volume of produced gas from 30 wells in Keenville was measured by Halliburton Resource Management on July 12, 1977. The production rate was 1429 thousand cubic feet (MCF) per day. Five samples were collected and analyzed. The gross heating value ranged from 1443 to 1595 BTU. Table 4 gives selected analytical results taken from the Halliburton report.

Currently the gas is being flared because the high cost of collecting and processing (estimated by Halliburton at approximately $1,500,000) makes the marketing of such a small volume of gas uneconomical. According to Fletcher Farrar, however, arrangements to market the gas were pending at the time of this writing.

METHOD OF DISCOVERY

Those who explore for oil are always interested in knowing what approach was used to discover a new pool or new pay zone. This interest with respect to the Salem may be more intense than usual because of the rather unpredictable nature of the porosity development in the biocalcarenite facies. Most of the recent successful Salem exploration has been confined to prominent structures (fig. 4) underlain by zones shallower than the Salem that are now producing oil or have produced it in the past.

According to Fletcher Farrar, the discovery well for Salem production at Keenville, the # 1 Roy Reed, was drilled on the premise that the Aux Vases Sandstone and McClosky lime were likely oil prospects. Farrar decided to take the test to the Salem Limestone in the event that the shallower objectives showed no oil accumulations. The Aux Vases was reported to carry a show of oil, but no shows were reported in the McClosky. The hole

TABLE 4. Results of gas analysis from Keenville field (Chromatographic method)

Component	Sample Number[a] 1 Mol %	2 Mol %	3 Mol %	4 Mol %	5 Mol %
Helium	-	-	-	-	-
Hydrogen	-	-	-	-	-
Carbon Dioxide	0.28	0.37	0.22	0.37	0.32
Nitrogen	4.45	4.31	4.39	5.07	5.15
Methane	49.87	48.91	50.07	52.35	56.17
Ethane	19.31	20.01	20.38	19.63	18.62
Propane	15.95	16.64	16.18	15.03	13.33
i-Butane	1.56	1.59	1.44	1.30	1.04
n-Butane	5.62	5.70	5.06	4.44	3.75
i-Pentane	0.88	0.81	0.71	0.60	0.51
n-Pentane	1.26	1.12	1.01	0.83	0.72
Hexanes-Plus	0.82	0.54	0.54	0.38	0.39
Totals	100.00	100.00	100.00	100.00	100.00
Gross Heating Value (BTU)[b]	1594.0	1595.6	1568.1	1503.2	1443.0

[a] Wells from which samples were collected shown in Appendix A.

[b] per cubic ft @ 60°F - 30" Hg. Sat.

was deepened to the Salem and three drill-stem tests were run. The best of these flowed gas to surface in 4 minutes and recovered 485 feet of oil. The tested zone (3584-3611) was from 140 to 167 feet below the reported Salem top. The well was subsequently completed with 24 perforations from 3612 to 3620. An initial production of 335 barrels of oil flowing per day with no treatment was reported.

CONCLUSIONS

The "key" to successful oil exploration in the Salem Limestone of the Illinois Basin is not yet known. Some degree of success has resulted from testing the Salem on known high structures that have production. This method has also produced some disappointing failures. Keenville certainly demonstrates that good Salem production can be found under structural noses that have no apparent closure. Additional drilling may provide data for further study of the deposition and diagenetic history of the Salem. Better understanding of this history should aid geologists in predicting the location of reservoir rocks in unexplored areas. This could lead to the projection of trends that would suggest the most favorable areas for oil accumulation. According to records kept at the Illinois State Geological Survey, over half of all the oil test holes drilled in Illinois during 1977 were drilled to the Salem Limestone or deeper. If this activity continues perhaps the kind of subsurface data needed for a better understanding of Salem oil accumulation will become available.

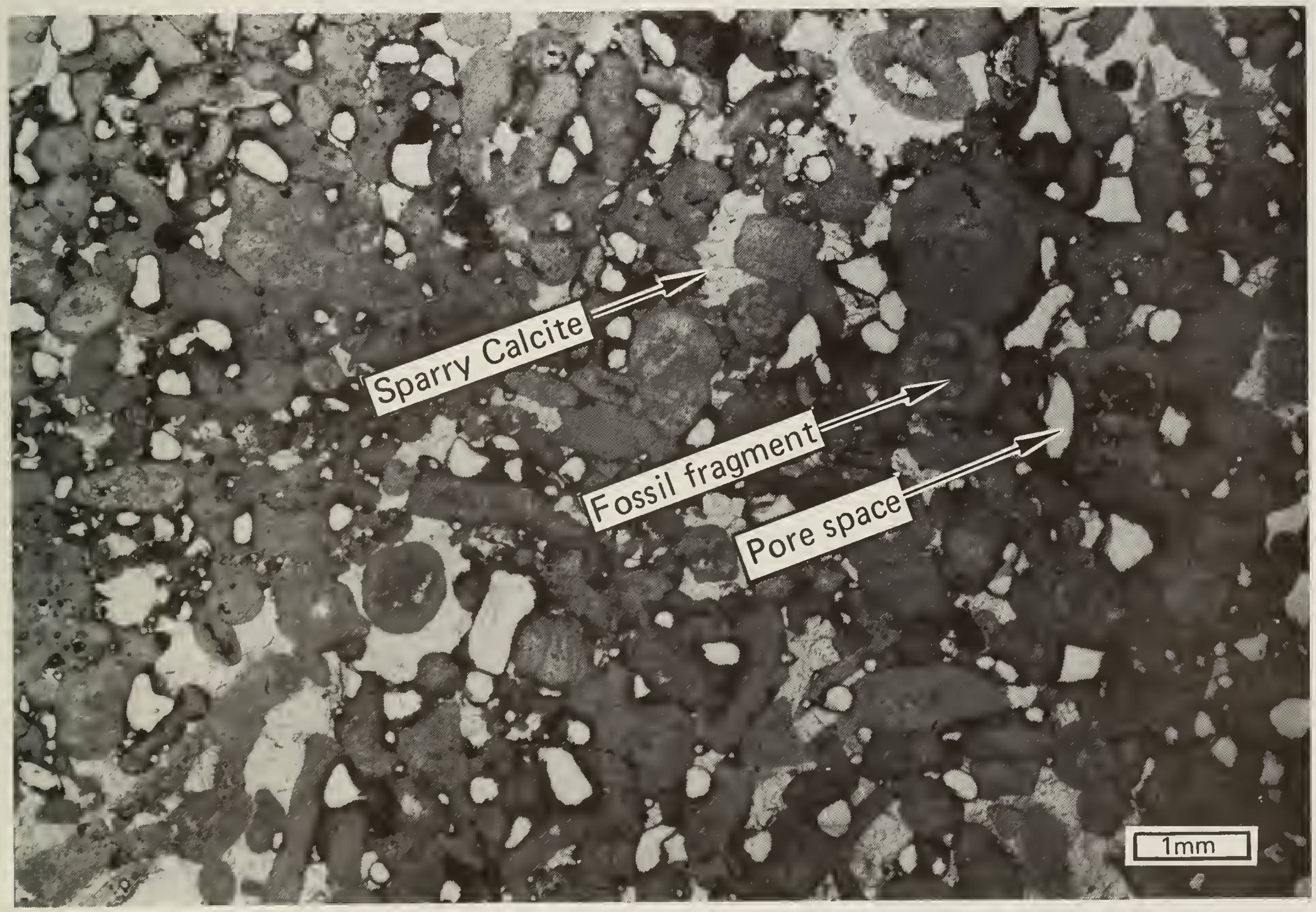


Figure 8. Enlarged photograph of a rock peel taken from Salem Limestone core in Keenville field.

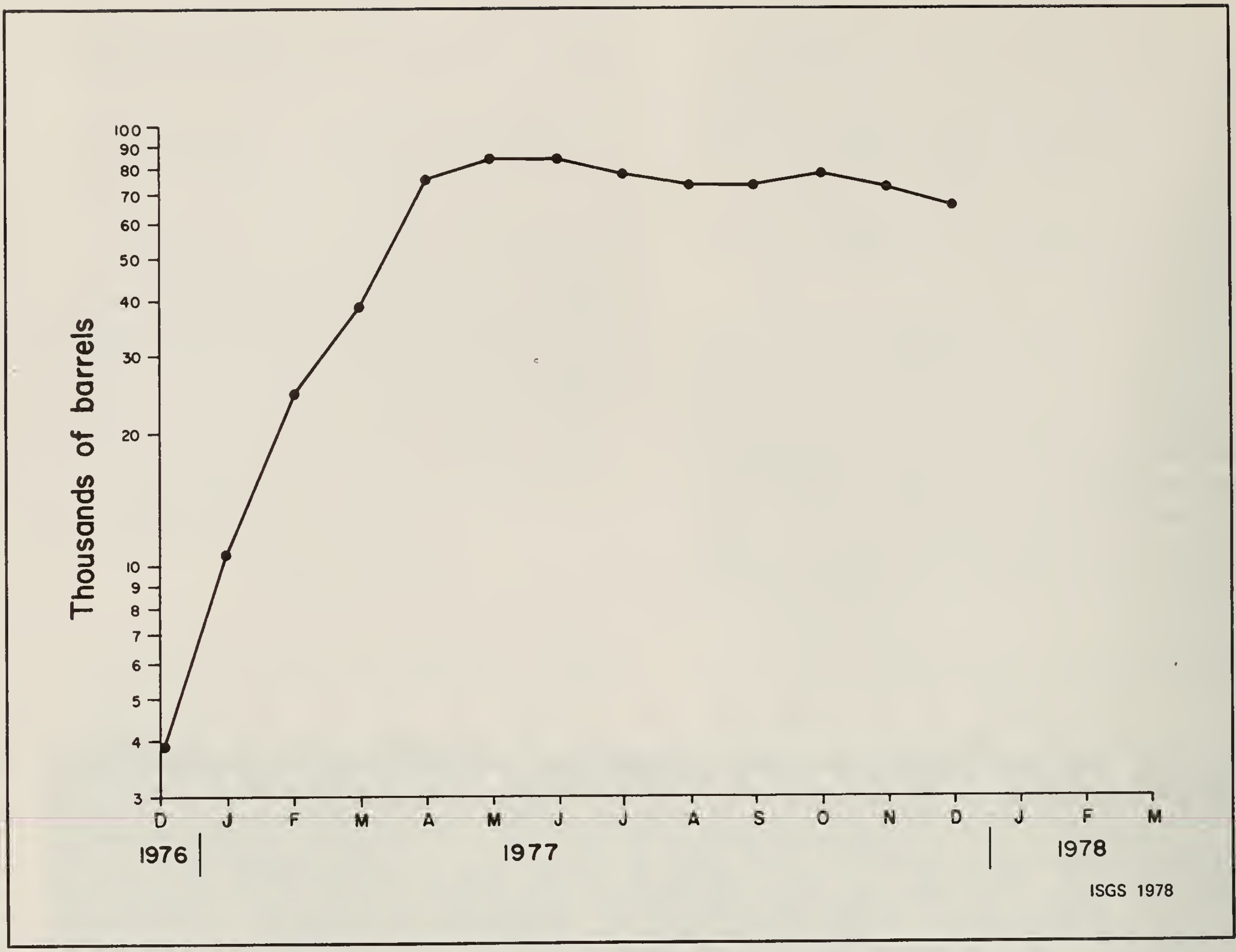


Figure 9. Salem oil production from Keenville field by month.

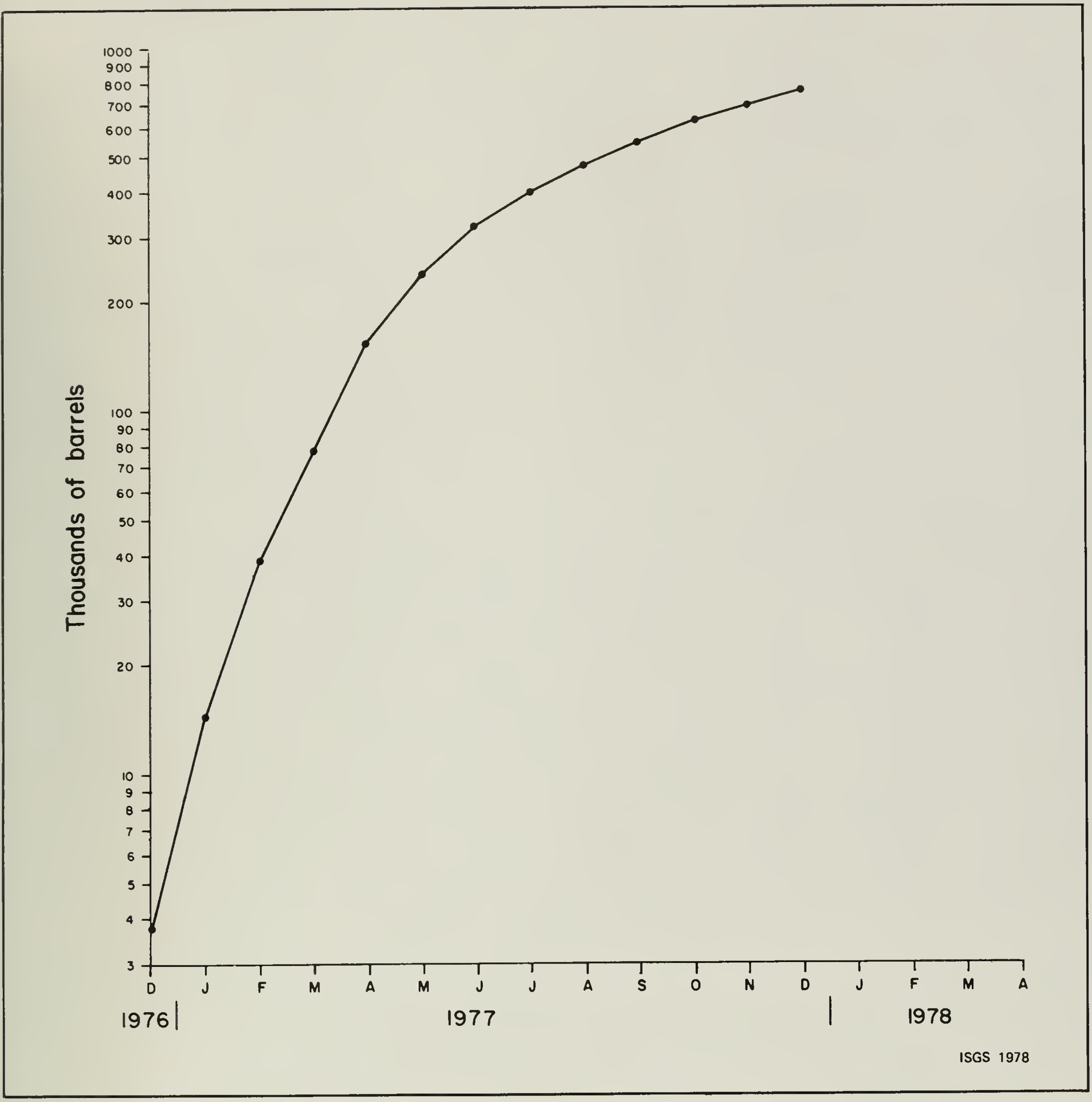


Figure 10. Cumulative oil production from Salem Limestone in Keenville field.

APPENDIX A

Wells supplying gas samples for analysis shown in table 4

Operator	Well No.	Farm
Farrar	1, 2, & 3	George Reed
	1 & 2	Verle Keen
	1	Keen Unit
	1, 2	Roy Reed
Pessina	1 through 7	Goff
Texaco	3 through 7	Tutt
Collins Brothers	1	R-E-S
	A-1 and B-1	Smith
Evans	1 & 2	Johnson
	1	Brown

APPENDIX B

Holes used in cross-sections (Figs. 3 and 4)

Company	Number	Farm	Location (all in T 1 S., R. 5 E.)
Beeson	1	Boyer et al.	380NL 330EL SE NE Sec. 33
Texaco	7	Tutt	330NL 990WL NE Sec. 34
Pessina	5	Goff	330SL 330WL SE SW Sec. 27
Pessina	2	Goff	330SL 330EL SE SW Sec. 27
Farrar	1	Johnson-Keen	330SL 330WL NW SE Sec. 27
Farrar	1	Keen	330NL 990WL SE Sec. 27
Farrar	3	Geo. Reed	330SL 330WL SE NE Sec. 27
Friend	1	Keen	330SL 330WL NE NE Sec. 27
Farrar	3	Roy Reed	585SL 330WL SW NW Sec. 27
Farrar	4	Roy Reed	330SL 255WL SE NW Sec. 27
Farrar	1	Johnson-Keen	330SL 330WL NW SE Sec. 27
Pessina	3	Goff	330NL 430EL SW SE Sec. 27
Pessina	7	Goff	390SL 990EL SE Sec. 27
Pessina	10	Goff	400NL 370EL NE NE Sec. 34

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